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Original Paper

The Influence of Eco-friendly Ash on Sustainable Construction Material: A Review

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Abstract

Nowadays climate change is one of the major concerning factors due to increasing temperature throughout the world. Carbon dioxide is a significant gas in the greenhouse effect which leads to global warming. The construction industries released 40% carbon emissions from thermal calcium carbonate decomposition especially in cement production and combustion of fossil fuels of non-renewable energy. Renewable energy acts a vital part in the evolution of sustainability. Bioenergy has been deliberated carbon neutral as the released carbon is absorbed by flora. This paper presents a comprehensive review of the pozzolanic properties of waste ash and the performance of concrete. Ash is a by-product produced from various resources such as rice husk, wood, coal, sawdust combustion, etc. Waste ash is reused as supplementary material in eco-friendly concrete production. This helps for the disposal of waste as well as contributes the sustainability by reducing carbon emission into the environment.

Keywords

eco-friendly concrete, waste ash, pozzolanic properties, review

1. Introduction

Concrete is generally used in the construction industries where have very few openings for innovative applications and construction practices (Kumar, 2012). Conventional construction materials are difficult to reach for a majority of people around the world due to their low affordability (UNCHS, 1993). Further, the increasing cost of building materials, rising environmental concerns due to the broad exploitation of natural resources associated with common development activities need to explore alternative technical options.

Many studies have been carried out continuously to make suitable concrete for construction purposes by assessing factors such as compressive strength, workability, and durability of the usual concrete. Most of these studies have been conducted to identify highly accessible materials used in construction activities as a solution to achieve the demand for raw materials. Commonly ash produced from various materials is used as a supplementary cementitious material to produce concrete where it has the properties of hardened concrete through pozzolanic activity (Bhatt et al., 2019).

Concrete blocks are produced using cement, fine aggregates, and crushed aggregates. These can be substituted in manufacturing blocks which improves the properties of concrete blocks.

Fly ash (Madhavi et al., 2013), rice hush ash, sawdust ash (Olufemi, 2020), coconut shell (Silva, n.d.), wood ash (Prabagar et al., 2015) (Chowdhury et al., 2015), corn cob ash (Adesanya & Raheem, 2009), palm oil waste ash (Nurdeen et al., 2011); groundnut husk ash, bagasse ash (Singh et al.,2000); waste tire ash (Aliyu et al., 2020) and natural fiber (Zakaria et al., 2015) can be used as partially replaced for cement. Ash is obtained from the complete combustion which contains inorganic incombustible biomass of minerals. Ash is used in many industrial processes of cement clinker, soil stabilizing binding material, fertilizers, blocks, and synthetic aggregates (Udoeyo, 2006).

2. Physicochemical Properties of Ash

Concrete properties are dependent on, composition and proportion of other ingredients, type and size of concrete, exposure conditions, and construction practices except for the amount of ash incorporated. The qualitative and quantitative characteristics of waste ash need to be acquired with concrete and cement paste characteristics. The factors include burning temperature, types and hydrodynamics of the furnace, and varieties of ash influence in the production of concrete. Physicochemical characteristics were measured in several studies for suitability for using cementitious material. Assessment of supplementary cementitious material was examined according to the American Society for Testing and Materials (ASTM). Table 1 shows the chemical composition of different ash varieties. Mostly, ash is rich in silica and low in calcite and ferric oxide compared to fly ash and wood ash. Other compositions vary depending on the resources of the ash obtained.

Ash incorporated cement has pozzolanic properties such as high compressive strength, lightweight, low water absorption, and thermal resistance make available for many applications. Physical and chemical characteristics that influence the re-use options involve applications such as soil stabilization for roadways, backfill for excavations, landfill liners, and geopolymer material. Physicochemical characteristics were measured in several studies for suitability for using cementitious material.

The loss of ignition (LOI) is a measure to detect the ratio of unburned carbon and metallic oxides in ash. The increase in LOI reduces the ash quality which impacts the concrete’s durability. LOI is lower in fly ash than the rice husk ask meanwhile LOI of wood ash varies according to the type of wood. Fly ash provides a better flowability of building motar (Li et al., 2022). Many varieties of ash have been used in cement industries; for the utilization of waste materials, decreasing energy consumption, reducing costs, and increasing technical benefits. It shows pozzolanic activity which contributes to the performance of hardened concrete. It improves the consistency and workability of Portland concrete. Control the heat of hydration, heat generation associated with cement hydration can be vital. Setting time will be increased when the high concentrated ash is used. The supplementary cement materials are inorganic materials used with Portland cement. It subsidizes the hydration reactions (Taylor, 1970).

3. Microstructure of Cement Paste Matrix

Ash incorporated concrete modify the microstructure of concrete by transporting water into it and improves the particle packing which reduces the concrete permeability leads to the durability of concrete.

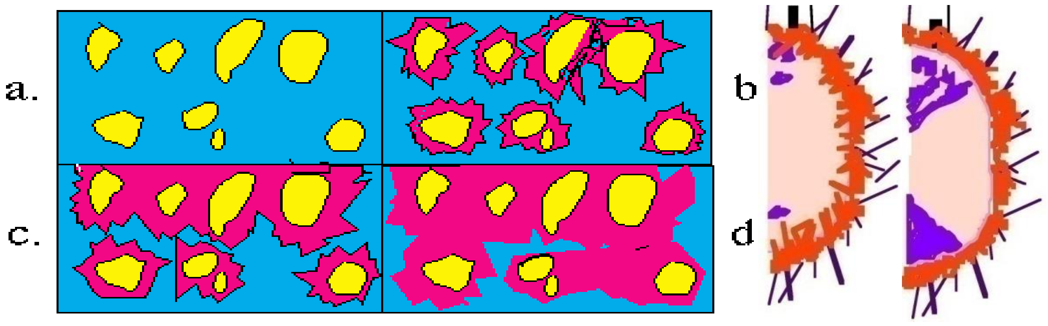

Figure 1. Schematic Illustration of the Pores in Calcium Silicate through Different Stages of Hydration

(https://www.concretedecor.net/decorativeconcretearticles/online-exclusives/scientific-principles/)

In Portland, cement silica compounds react with calcium hydroxide to form cementitious properties (Figure 1). Therefore, low calcium content ash is mixed with an activator of quicklime to produce cement in the presence of water. While Portland cement was added to the water, calcium silicate hydrate (CSH) and free lime (CaOH) were formed. Free lime was water-soluble. But, when adding cementitious ash materials was mixed with Portland cement-free lime was again reacted with ash and formed calcium silicate hydrate. It improves the durability of concrete. Ash incorporated cement material contributes (thermal resistance) to strength improvement at a lower temperature (400 ℃) and to minimize strength loss up to 600 ℃ as compared to Portland cement. Due to the pozzolanic activity of ash causing more C-S-H formed, along with a reduced amount of CH; decreases the surface cracks in cement and the risk of explosive spalling. Therefore, total porosity and average pore volume become lower than the Portland cement. Low vapor pressure during heating of concrete with ash, decreases thermally induced explosive spalling (Pawel Sikora et al., 2018).

4. Varieties of Ash Used in Cement Industries

4.1 Rice Husk Ash

Rice husk is the hard protective shell of rice grain obtained as a by-product in rice mills in many developing nations. Rice husk ash (RHA) is a waste from the burning of rice husk consists of 40% lignin, and 20wt % silica (He et al., 2013). Rice husk ash-based concrete was patented in 1924 where the used ash is obtained in uncontrolled combustion mentioned by Stroven (1999). The researcher Mehta (1978) established the method of burning rice husk under controlled temperature-time conditions that produces ash containing silica is in the amorphous. Chopra, Ahluwalia and, Laxmi have stated that the silica was in amorphous form in an incinerator temperature up to 700 ℃ and silica crystals grew with the time of incineration. The combustion environment, time and, temperature need to be considered in the pyro processing of rice husks to produce ash of maximum reactivity by increasing the specific surface area (crossref) (Nair et al., 2006).

Rao revealed that isothermal heating at a minimum of 402 ℃ is required for the destruction of organic matter from rice husk to produce silica. Generally cellulose - lignin matrix has burnt on combustion leaving a porous silica skeleton. While grinding, it gives very fine particles with a large surface area. The ability to crystalline growth and pore opening occurs by decreasing surface area (Rao et al., 2014).

M.R.Yogananda and K.S.Jagadish from the Indian Institute of Science (IISC), Bangalore had done several studies on the pozzolanic properties of rice husk ashes produced by different types of field incinerators. Rice husk has recently been recognized as pozzolana with siliceous material which has minute cementitious value. The moisture reacts with calcium hydroxide released from the hydration of cement to produce the stable, insoluble cementitious compound. The addition of rice husk ash with Portland cement forms a calcium silicate hydrate (CSH) gel around the cement particles. The strength against cracking is increased due to the highly dense and less porous concrete structure (crossref) (Nair et al., 2006). Lightweight concrete blocks have been made from partly burnt rice husks. Blocks that have been made using cement and husk ash resist very high temperatures and act as an insulator (Grith, 1974).

As Sri Lanka is a tropical country, warm climate conditions are revealed the hot discomfort within the built environment. Many building constructors use fans and air conditioners to cover indoor thermal comfort. However, rice husk-incorporated cement facilitates better indoor thermal comfort (Prabagar et al., 2015). Rice husk ash sand cement provides a thermally comfortable indoor environment due to its water absorption capability (Nilantha et al., 2010).

Sri Lanka is a developing country, as well as a rice growing nation, and sand cement blocks, consist of sand, cement, and water, are widely used. The researchers indicated that rice husk incorporation with cement provides an adequate level of strength and thermal comfort as well as low cost.

The silica in the ash undergoes structural changes depending on the time and temperature of combustion. Amorphous ash is formed at 550 ℃ - 800 ℃ and crystalline ash is formed while increasing the temperature. These types of silica have different properties and it is important to produce ash of the correct specification for the particular end use (Prabagar et al., 2015).

Rice husk ash is a very fine powder with25-micron size and grey in colour. The cement properties of water absorption and compressive strength vary with the type of ash formed due to the different burning techniques. It may be cost-effective and advantageous if they use for manufacturing sand cement blocks with suitable compressive (Dabai et al., 2009). Many research studies mentioned that 10% rice husk ash replacement in cement production, shows better compressive strength which ranged from 29.28 to 38.2 MPa in 28 days of curing period (Surya Veera Vasudeva Rao and Manideep Tummalapudi, 2012; Rajput et al., 2013; Rao et al., 2014; Nilantha et al., 2010; Dabai et al., 2009). The compressive strength increases at temperatures from 100 ℃ to 150 ℃; then it decreases at higher temperatures due to pore water evaporates at 100 ℃ and the concrete becomes brittle.

Fly ash (21%) mixed with rice husk ash (9%) replaced cement showed increased compressive strength (42.9MPa). The flexural and split tensile strengths of that cement were 8.5 & 3.67 MPa respectively. Initial setting time was longer (136 - 175min) and final setting time was lesser (227 - 265) than normal concrete which has initial and final setting times of 50 and 365 minutes (Kene et al., 2011) (Rao et al., 2014) (Dabai et al., 2009) (Indian Standard code of practice for plain and reinforced concrete, IS 456-2000).

The pH of the hydrated cement mixture should be maintained at 13±1 for the stabilization process and increasing the compressive strength. Hydration occurs when water is added to the cement. In the presence of RHA, the fine material of SiO_2 absorbs water first before starts the hydration of the cement materials. Therefore, retardation effects of RHA were observed on the setting time. The initial and final setting times increase while increasing rice husk ash content. Water mixed cement reaction is exothermic. Therefore, the release of heat evaporates the water which stiffens the cement mixture due to its lower cement/rice husk ash mixture. It was observed in the longer initial setting time (RHA 10%, 20%, 50% - in min 136, 154, 281). This was agreed with the work of Dashan and Kamang (1999) and that of Oyetola and Abdullahi (2004) (crossref) (Dabai et al., 2009). And the increase in setting time of mixture having rice husk ash revealed a low level of hydration, which produces calcium hydroxide ($Ca(OH)_2$).

Concrete needs more water in the mixture while increasing the rice husk ash due to the highly porous structure. Rice husk ash provides thermal insulation and increases the strength of cement because it has produced more than 80% of silica. The fineness of cement was 369 whereas control was 300 (min, IS 1489 - 1991) (Rao et al., 2014). The total percentage composition of iron oxide (Fe_2O_3-1.56%), Silicon dioxide (SiO_2-91.75%), and Aluminium Oxide (Al_2O_3-2.07%) was found to be 95.38%. The compressive strength was 2.928 and the standard value was 2.8 Nmm^{-2} according to BS 6073: Part 2: 1981. Water absorption was 16.583 and the acceptable value is 12% for masonry blocks according to BS 5628: Part 1: 2005.

4.2 Wood Ash

Many studies (Udoeyo et al., 2006; Naik et al., 2003; Elinwa & Mahmood, 2002; Elinwa et al., 2008) were performed for the feasibility of the use of wood waste in concrete production They had common findings that wood ash replacement from 5% to 30% reduces compressive strength of concrete (Udoeyo & Dashibil, 2002; Elinwa & Ejeh, 2004; Abdullahi, 2006). It can be used during concrete production with acceptable mechanical and durability properties (Ban & Ramli, 2014). The typical combustion temperature of wood waste is 1000 ℃. At higher the reduction of waste wood ash yielded up to 45% with a combustion temperature increases from 538 ℃ to 1093 ℃. Calcites (CaCO3) are predominant in wood ash at lower than 500 ℃ incinerated temperature whereas calcium oxide (quick lime) is predominant at higher (greater than 1000 ℃) incinerated temperatures.

Ash quality may vary with the factors such as burning temperature, wood species, and burning technique used. Chemical composition in wood ash differs from wood species, but they consist of silica and lime. A high specific area was found in wood ash due to its porous nature. Increased incorporation of ash in cement decreases the decline of concrete. Up to 10% replacements of ash produce better structure-grade concrete. Water absorption increases and decreases in drying shrinkage when increasing the ash content.

Generally, wood ash is an angular shape with different-sized particles. The average percentage of wood ash passing sieve #325 (45μm) is 31% and the mean specific gravity was 1.65 (unit wt 827kgm^{-3}) (Naik et al., 2003). The physical properties of specific gravity (2.43), moisture (1.81%), pH (10.48), and LOI (10.46) were observed in the study done by Udoeyo et al. (2002). Specific gravity was observed as 2.54 in the study (Rajamma et al., 2009) fine particles were observed in 50μm.

Udoeyo et al. (2006) stated that wood ash particles act as filler material than as binder. Therefore, increasing ash replacement caused an increased surface area of filler which lowered the cement strength. A higher compressive strength was found in the concrete mix with wood ash replacement from 15% to 25% of binder weight (Udoeyo & Dashibil, 2002). This evidences the increased CSH gel formation within cement mix microstructure of wood ash concrete by pozzolanic activity which was formed between silica of wood ash and portlandite from cement hydration. The highest compressive strength was exhibited in 10% wood ash replacement in all curing ages up to 60 days and the strength was equivalent with Portland cement (Elinwa & Ejeh, 2004; Naik et al., 2002; Elinwa et al., 2008; Rajamma et al., 2009).

Acquired compressive strength of control concrete and concrete with 12% wood ash were 34MPa and 33Mpa in 28 days; 44Mpa and 42-46Mpa in 365 days. The replacement percentage had a significant contribution to the strength development of concrete produced. This shows an occurrence of pozzolanic reactions between wood ash and the cement hydration product. Elinwa et al. (2005) used 3% (by total weight) of metakaolin as an additive material in the concrete mixture. This enhances the compressive strength of wood ash (10%) concrete than the portland cement. High rates of the pozzolanic reaction which was initiated in 28 days of cure high due to very fine particle size and high surface area of the ash.

The split tensile strength of concrete with wood ash was found to decline with increasing wood ash replacement. The reduction in split tensile strength of concrete was less evident in comparison with a reduction in compressive strength (Udoeyo & Dashibil, 2002). The obtained split tensile strength of control concrete and concrete with 8% wood ash were 3.8MPa and 3.6-4.0Mpa in 28 days; 4.3Mpa and 4.3-5.3Mpa in 365 days. The concrete with 8% wood ash showed the best split tensile strength behaviour (Naik et al., 2002).

The obtained flexural strength of control concrete and concrete with 5% wood ash were 4.1MPa and 3.9-4.4Mpa in 28 days; 4.4Mpa and 4.3-5.3Mpa in 365 days. The concrete with 5% wood ash showed the best flexural in 7 days and 8% showed best in 28-365 days strength behaviour (Naik et al., 2002). Udoeyo et al. (2006) stated that there was an increased level of wood ash that resulted in a decreased degree of flexural strength. Results exhibited a decline from 5.20MPa with 5% wood ash concrete to 3.74MPa with 30% wood ash concrete at 28 days. At 28 days, the flexural strength of the concrete with 5% wood waste ash content was 5.20MPa as compared to 5.57MPa in control concrete. A gradual reduction occurred in the flexural strength over 28 days.

Wood ash can be used in the mortar at a cement replacement level of up to 20% to maintain acceptable mechanical strength; and (ii) mechanical strength of mortar deteriorated rapidly with the incorporation of wood waste ash at cement replacement level higher than 20%.

4.3 Sawdust Ash

Sawdust is a waste produced from timber mechanical mills of various sizes. Sawdust ash (SDA) has pozzolanic characteristics which were confirmed through research studies. It can be partially replaced with ordinary Portland cement (OPC) and concrete (Olufemi, 2020) [36, 37, 38]. SDA is favorable in concrete due to the low heat of hydration and later stage strength gaining. Up to 15% SDA replacement is adequate for maximum benefit in compressive and flexural strength of the OPC-clinker-SDA blend. physical characteristics of SDA blended cement consist of Fineness 411 km^{-2}; soundness 6mm; initial setting time 75min; final setting time 90; consistency 30.4%; residue on 45um sieve 24.25%; specific gravity 2.32; LOI 1.48 (Raheem & Ige, 2018).

4.4 Fly Ash

Fly ash is the residue produced from the combustion of pulverized coal by coal-fired electric and steam-generating plants (Amran et al., 2020). Fly ash was estimated at 363 million tons annually in India which is the leading producer followed by China and the US (Gollakota et al., 2019). Utilizing fly ash in concrete has more environmental benefits such as: increasing the life of the concrete by improving concrete durability; reducing greenhouse gas emissions; reducing coal combustion waste and conversion of natural resources. Fly ash is a fine powdered particle; spherical in shape and amorphous in nature. The specific gravity of coal ash varies from 1.6 to 3.1 (Pandian et al., 1998). Fly ash has a high surface area with low bulk density (Ram & Mastro, 2014). Its colour varies from orange to deep brown or white to yellow due to the unburned carbon and iron incorporated into the ash

(Ahmaruzzaman, 2010). Studies revealed that 15 - 25% fly ash incorporated concrete contributes to the durability of hardened concrete (Thomas et al., n.d.).

Fly ashes are classified into two types as Class C and Class F in cement industries. According to the American Society for Testing Materials Standards ASTM C618, ash containing more than 70% SiO_2+Al_2O_3+Fe_2O_3 (wt) is categorized as Class F and those in between 50 - 70% chemical content is defined as Class C. And the contents such as SO_3 (< 5%), moisture (<3%), Na2O (<1.5% optional), particle size (< 34%, on average 5% retained on 45μm), loss of ignition (LOI) (6% and up to 12%) need to be accompanied in ASTM system for class F ash (ASTM, 2005). According to ASTM, Class C fly ash contains higher calcium content (as CaO > 15%) than in Class F fly ash (as CaO < 5%). Alkali and sulfate content are also high in Class C fly ash (Ramme & Tharaniyil, 2004).

Several pieces of research had been conducted in fly ash incorporated cement. The authors observed that the compressive strength of concrete reduces with the increased fly ash replacement (R.D.Padhye and N.S. Deo - crossref) compared with 53 grade Portland cement. The replacements of fly ash of 0,10, 20, 30, 40 50% in the concrete experiment showed that concrete with 30% fly ash had the highest compressive strength 45.28Nmm^{-2} after 28 days. Except for 50% of fly ash incorporated concrete, other types of cement show high strength than conventional concrete (Mohammad Abushad, Misbah Danish Sabri). Fly ash 0, 5, 10, 15, 20% substituted fly ash study showed that 20% fly ash concrete exhibited the highest compressive strength and split tensile of 37.40 Nmm^{-2} and 3.01 Nmm^{-2} respectively in 28 days (Siddamreddy Anil, Kumar Reddy, Dr. K. Chandrasekhar Reddy). Fly ash 0, 10, 20, 30 - 20% fly ash concrete showed that flexural strength was increased by 11.08% others lower than 0% concrete (Jayraj Vinodsinh Solanki, Jayeshkumar Pitroda). Concrete with 0, 10, 20% fly ash and 0, 0.5 & 1.0% steel fiber was produced and the highest flexural strength was observed in 10% fly ash and 0.5% steel fiber incorporated concrete 3.7, 5.89 & 6.35Nmm^{-2} after 28 days 1.5% is added of aspect ratios 20mm, 30mm and 40mm (Resmi Madhavan, Sudheer. K.V, Chittilappilly). The use of a super-plasticizer enhances flexural strength. 35% of fly ash incorporated 0.4W/C ratio concrete shows the highest compressive strength (30.61Nmm^{-2}) and flexural strength (4.85Nmm^{-2}) in 28 days of curing period compared to 45% and 55% ash concrete (Shiv Kumar et al,). Fly ash 30, 40, 50 - 30% fly ash showed the highest flexural strength after 28 days. (cross-ref; Krithika & Kumar, 2020).

It was observed in 50 - 70% ash replacement, high volume fly ash replacement caused a reduction in temperature increase and induced in the concrete low porosity and permeability (Cengiz Duran Atis). The degree of hydration was determined using non-evaporable water content in the 0%, 25%, 45%, and 55% of fly ash was replaced concrete. A low degree of fly ash reaction was occurred in high volume fly ash compared with less amount of fly ash. The hydration was not adequate in a high-volume fly ash concrete. However, another study revealed that the addition of Nano SiO_2 (50% fly ash and 2% nano SiO_2) showed high volume fly ash with higher compressive strength than conventional Portland cement at 112 days. After 2 years, high volume fly ash concrete added nano SiO_2 showed an increase in strength by 11% than Portland cement (Gengying Li) thus, the use of a high volume of fly ash results in high-performance concrete which consists of high strength, durability, and workability (crossref; Krithika & Kumar, 2020).

Fly-ash-based geopolymer (FA- GPC) concrete constitutes only the fly ash. It acts as a binder as the silicon and aluminum and it is activated using alkaline liquids. This research study concluded that FA-GPC has impressive compressive strength, excellent durability, reduced permeability has little drying shrinkage, and is resistant towards sulfate attack (Djwantoro Hardjito, Steenie E Wallah, Dody MJ Sumajouw, & B Vijaya Rangan). High- Calcium FA- GPC was prepared and 10, 15, and 20M NaOH was used in this study. The compressive strength was slightly lower and split tensile strength was 10% higher than the conventional Portland cement after 7 days. It showed that the density was 30% lower than that of porous concrete made with Portland cement (Tawatchai Tho-ina, Vanchai Sataa, Prinya Chindaprasirta, ChaiJaturapitakkulb) (crossref; (Amran et al., 2021).

FA-GPC shows the resistance to chloride attack by reducing the chloride ions penetration when increasing the NaOH ratio utilized in the geopolymeration process. Thus, FA-GPC shows the aperture structure with less chloride dispersal and low permeability than Portland cement. Furthermore, it has high compressive strength and high fire resistance than Portland cement.

Reviews exhibit that a durable FA- GPC is a new sustainable concrete material including high early strength, reduced permeability by producing denser concrete with a small size of pores. Fly ash concrete is recyclable, eco-friendly GPC and it contributes to a safe environment. However, FA is believed as one of the alternative supplemental cementing materials in concrete for the production of renewable and green concrete (Amran et al., 2021).

It is known that the increase in demand for cement production is because of the fast construction techniques, industrial revolution, and increase in population worldwide. Such a huge quantity of organic waste of fly ash creates problems such as increasing disposal of landfills, carbon footprints and needs proper waste management. It is stated that the durability of fly ash-based eco-friendly geopolymer concrete depends on fly ash type, alkaline activator concentration, curing time and temperature, and the geopolymeration process.

Fly ash geopolymer concrete (FA- GPC) has exhibited better strength properties than conventional concrete. It leads to safe dumping, avoid health and reduce environmental issues by decreasing the emissions of CO_2. The refined pores by fly ash particles may decrease the permeability of the FA-GPC and increase the porosity which is greater than the Portland cement.

4.5 Coconut Husk Ash

Coconut husk is hard, medium brown, and has a rough, hairy surface that is called coconut shell. After using coconut fruit, the coconut shell is released into the environment. Even, it has several usages, a considerable amount of them was thrown as waste. These are widely used in the handicraft industry for making value-added aesthetic products which have contributed to earning foreign exchange.

It is very hard characteristics and may be used for coarse aggregate in the masonry blocks. Considering the properties of coconut shell and rice husk ash structural performances are the most important factors when using these masonry blocks. Cost-effective and lightweight materials are preferred in masonry block preparation. Also, light-weight masonry blocks with sufficient compressive strength will be a major benefit and easy handling in building construction lightweight masonry blocks can be made due to the low density of coconut shell compared to the coarse aggregate (Silva, n.d.; Prakash & Raman, 2019; Zakaria et al., 2015).

5. Summary

The demand for cement production is increased due to the industrial revolution and increasing population. Cement plants cause an ecological issue by releasing CO_2 which leads to global warming. Therefore, eco-friendly supplementary materials with pozzolanic properties need to be used. The review directed the effect of waste ash produced from rice husk, coal, wood, and sawdust combustion in cement production. These recycled materials have high alumina and silica that provide cementitious characteristics in the presence of water. The low percentage of substitution (up to 30%) of waste ash gains greater strength and durability than conventional concrete. The use of waste ash in cement review shows safe dumping of waste, reduction of environmental pollution, and decrease the emission of CO_2.

References

Abdullahi M. (2006). Characteristics of wood ash/OPC concrete. *Leonardo Electronic J. Pract. Techno.*, *8*, 9-16.

Adesanya, D. A., & Raheem, A. A. (2009). Development of corn cob ash blended cement. *Construction and Building Materials*, *23*(1), 347-352. https://doi.org/10.1016/j.conbuildmat.2007.11.013

Ahmaruzzaman, M. (2010). A review on the utilization of fly ash, Prog. *Energy Combust. Sci.*, *36*(3). 327-363.

Aliyu, M. M., Uche, O. A., & Adamu, M. (2020). Mechanical Properties of Waste Tyre Ash (WTA) Concrete. February. https://doi.org/10.5281/zenodo.3634359

American Society for Testing and Materials, Committee C-9 on Concrete and Concrete Aggregates. Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete, ASTM Int. (2005).

Amran, M., Debbarma, S., & Ozbakkaloglu, T. (2021). Fly ash-based eco-friendly geopolymer concrete : A critical review of the long-term durability properties. *Construction and Building Materials*, *270*, 121857. https://doi.org/10.1016/j.conbuildmat.2020.121857

Antiohos, S. K., Papadakis, V. G., & Tsimas, S. (2014). Cement and Concrete Research Rice husk ash (RHA) effectiveness in cement and concrete as a function of reactive silica and fineness. *Cement and Concrete Research*, *61-62*, 20-27. https://doi.org/10.1016/j.cemconres.2014.04.001

Ban, C. C., & Ramli, M. (2014). The implementation of wood waste ash : Review Paper Resources, Conservation, and Recycling The implementation of wood waste ash as a partial cement replacement material in the production of structural grade concrete and mortar : An overview.

Resources, Conservation & Recycling, *55*(7), 669-685. https://doi.org/10.1016/j.resconrec.2011.02.002

Batt, A. S. (2017). Partial Replacement of Wood Ash with Ordinary Portland Cement and Foundry Journal of Civil & Environmental Partial Replacement of Wood Ash with Ordinary Portland Cement and Foundry Sand as Fine Aggregate. January, 3-8. https://doi.org/10.4172/2165-784X.1000272

Bhatt, A., Priyadarshini, S., & Acharath, A. (2019). Case Studies in Construction Materials Physical, chemical, and geotechnical properties of coal fly ash : A global review. *Case Studies in Construction Materials*, *11*, e00263. https://doi.org/10.1016/j.cscm.2019.e00263

Chowdhury, S., Maniar, A., & Suganya, O. M. (2015). Strength development in concrete with wood ash blended cement and use of soft computing models to predict strength parameters. *Journal of Advanced Research*. https://doi.org/10.1016/j.jare.2014.08.006

Dabai, M. U., Muhammad, C., Bagudo, B. U., & Musa, A. (2009). Studies on the Effect of Rice Husk Ash as Cement Admixture. 17, 252-256.

Gollakota, A. R. K., Volli, V., & Shu, C. M. (2019). Progressive utilization prospects of coal fly ash: a review, Sci. Total Environ. https://doi.org/10.1016/j.scitotenv.2019.03.337.

Grith, D. H. (1974). *Rice*, 2nd Edition, Longman Limited, London. 12-18.

He, J., Jie, Y., Zhang, J., Yu, Y., & Zhang, G. (2013). Synthesis and characterization of red mud and rice husk ash-based geopolymer composites. *Cement and Concrete Composites*, *37*(1), 108-118. https://doi.org/10.1016/j.cemconcomp.2012.11.010.

https://www.concretedecor.net/decorativeconcretearticles/online-exclusives/scientific-principles/

Kene, S. D., Domke, P. V, Deshmukh, S. D., & Deotale, R. S. (2011). Assessment Of Concrete Strength Using Flyash And Rice Husk Ash. *International Journal of Engineering Research and Applications*, *1*(3), 524-534.

Krithika, J., & Kumar, G. B. R. (2020). Materials Today : Proceedings Influence of fly ash on concrete - A systematic review. Materials Today: Proceedings. https://doi.org/10.1016/j.matpr.2020.06.425

Kumar, P. R. S. (2012). Experimental study on the properties of concrete made with alternate construction materials. 2, 3006-3012.

Li C, Geng H, Zhou S, Dai M, Sun B., & Li, F. (2022). Experimental Study on Preparation and Performance of Concrete With Large Content of Fly Ash. Front. Mater. 8, 764820. https://doi.org/10.3389/fmats.2021.764820

Leroy, M. N. L. (2019). Valorization of Wood Ashes as Partial Replacement of Portland Cement : Mechanical Performance and Durability. *European Journal of Scientific Research*, *151*(4), 468-478.

Naik, B. T. R. (2002). Utilization Concrete Brick and Block Manufacturing.

Nair, D. G., Jagadish, K. S., & Fraaij, A. (2006). Reactive pozzolanas from rice husk ash : An alternative to cement for rural housing. 36, 1062-1071.

https://doi.org/10.1016/j.cemconres.2006.03.012

Ngueyep, M., Leroy, L., Tchouata, K., Hermann, J., Nkene, A., Rose, E., … Bienvenu, N. J. (2018). Density and Strength of Mortar Made with the Mixture of Wood Ash, Crushed Gneiss, and River Sand as Fine Aggregate. 109-120. https://doi.org/10.4236/msce.2018.64012

Nilantha, B. G. P., Jiffry, I., Kumara, Y. S., & Subashi, G. H. M. J. (2010). STRUCTURAL AND THERMAL PERFORMANCES OF RICE HUSK ASH (RHA). December, 13-14.

Nurdeen, M. A., Megat, A. M., & Syed, F. S. (2011). Influence of Calcination Temperature on Characteristics and Pozzolanic Activity of Palm Oil Waste Ash. *Australian Journal of Basic and Applied Sciences*, *5*(11). 1010-1018.

Olufemi, F. S., & O. A. (2020). Permeation Resistance of Sawdust Ash Blended Cement Laterized Concrete. *21*(2), 76-83. https://doi.org/10.9744/CED.21.2.76-83

Pandian, N.S., Rajasekhar, C., & Sridharan, A. (1998).Studies of the specific gravity of some Indian coal ashes. *J. Test. Eval.*, *26*(3), 177-186.

Pawel Sikora, Elrahman, M. A., & Dietmar, S. (2018). The Influence of Nanomaterials on the Thermal Resistance of Cement-Based Composites- A Review. 1-33. https://doi.org/10.3390/nano8070465

Prabagar, S., Subasinghe, K., Shanmugarajah, S., & Fonseka, W. R. K. (2015). WOOD ASH AS AN EFFECTIVE RAW MATERIAL FOR CONCRETE BLOCKS. *International Journal of Research in Engineering and Technology*, *3*(13), 1-6.

Prakash, R., & Raman, S. N. (2019). Mechanical characterization and flexural performance of eco-friendly concrete produced with fly ash as cement replacement and coconut shell coarse aggregate Mechanical characterization and flexural performance of eco-friendly concrete produced with fly as. January. https://doi.org/10.1504/IJESD.2019.10020909

Raheem, A. A., & Ige, A. I. (2018). Author's Accepted Manuscript. *Journal of Building Engineering*. https://doi.org/10.1016/j.jobe.2018.10.014

Rajamma R, Ball RJ, Tarelho LAC, Allen GC, Labrincha JA, Ferreira VM. (2009). Characterization and use of biomass fly ash in cement-based materials. *J Hazard Mater.*, *172*, 1049-60.

Ramme, B. W., & Tharaniyil, M. P. (2004). Coal Combustion Products Utilization Handbook, 3rd edition, Wisconsin Electric Power Company.

Ram, L. C., & Masto, R. E. (2014). Fly ash for soil amelioration: a review on the influence of ash blending with inorganic and organic amendments. *Earth. Rev.*, *128*, 52-74.

Rajput, J., Yadav, R. K., & Chandak, R. (2013). The Effect Of Rice Husk Ash Used As Supplementary Cementing Material On Strength Of Mortar. *3*(3), 133-136.

Rao, P. P., Kumar, A. P., & Singh, B. B. (2014). A Study on Use of Rice Husk Ash in Concrete. *0033*, 75-81.

Silva, S. De. (n.d.). Investigation on Compressive strength of masonry blocks manufactured using Crushed Coconut Shells.

Singh, N. B., & Singh, V. D. (2000). Hydration of Baggaste Ash blended Portland Cement. *Cement, and Concrete Research*, *30*(2000), 1485-1488.

Surya Veera Vasudeva Rao, & Manideep Tummalapudi. (2012). Performance of Rice Husk Ash Concrete at Elevated Temperatures. *International Journal of Earth Science and Engineering*, *05*(03), 3-6.

Taylor, H. F. W. (1970). Cement Chemistry (1st ed.). Thomas Telford, London.

Thomas, M. D. A. (2007). Optimizing the Use of Fly Ash in Concrete, Vol. 5420, Portland Cement Association, Skokie, IL.

Thomas, B. M., Ph, D., Eng, P., Engineering, C., & Brunswick, N. (n.d.). Optimizing the Use of Fly Ash in Concrete.

Udoeye, F. F., & Deshibi, P. U. (2002). Sawdust ash as concrete material. *Journal of Materials in Civil Engineering*, *14*(2), 173-176.

UNCHS (1993). Building materials for housing, report of the executive director. *United Nations Commission on Human Settlements, Habitat International*, *17*(2), 1-20.

Vassilev S. V., Baxter, D., Andersen, L. K., & Vassileva, C. G. (2010). An overview of the chemical composition of biomass. *Fuel*, *89*, 913-33

Zakaria, N. Z., Sulieman, M. Z., & Talib, R. (2015). Turning Natural Fiber Reinforced Cement Composite as Innovative Alternative Sustainable Construction Material: A Review Paper. *8*, 24-31.